JIS B 9702 (2000) (English): Safety of machinery -- Principles of risk assessment

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Safety of machinery — Principles of risk assessment

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of International Trade and Industry through deliberations at the Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law:

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In the event of any doubts arising as to the contents, the original JIS is to be the final authority.

Contents

Safety of machinery—Principles of risk assessment

Introduction This Japanese Industrial Standard has been prepared based on the first edition of ISO 14121 *Safety of machinery—Principles of risk assessment* published in 1999 without modifying the technical contents.

The quotation of EN 292-2:1991/A1:1995 in annex A (informative) of the said standard left as it is in this Standard because the annex is only informative.

The description concerning "European equivalents to cited normative International Standard", contained in the bibliography of the said standard, is not suitable for JIS and eliminated from this Standard.

The function of this Standard is to describe principles for a consistent systematic procedure for risk assessment as introduced in clause 5 of ISO/DIS 12100-1.

This Standard gives guidance for decisions during the design of machinery (see 3.11 of ISO/DIS 12100-1) and will assist in the preparation of consistent and appropriate Type B and Type C standards in order to comply with the essential safety and health requirements.

By itself this Standard will not provide presumption of conformity to the essential safety and health requirements (see annex A of ISO/DIS 12100-1).

1 **Scope** This Japanese Industrial Standard establishes general principles for the procedure known as risk assessment, by which the knowledge and experience of the design, use, incidents, accidents and harm related to machinery is brought together in order to assess the risks during all phases of the life of the machinery [see 3.11 a) of ISO/DIS 12100-1].

This Standard gives guidance on the information required to allow risk assessment to be carried out. Procedures are described for identifying hazards and estimating and evaluating risk. The purpose of the International Standard is to provide advice for decisions to be made on the safety of machinery and the type of documentation required to verify the risk assessment carried out.

This Standard is not intended to provide a detailed account of methods for analysing hazards and estimating risk, as this is dealt with elsewhere (e.g. text books and other reference documents). A summary of some of these methods is given for information only (see annex B).

Note : The International Standard corresponding to this Standard is as follows.

In addition, symbols which denote the degree of correspondence in the content between the relevant International Standard and JIS are IDT (identical), MOD (modified), and NEQ (not equivalent) according to ISO/IEC Guide 21.

ISO 14121:1999 *Safety of machinery—Principles of risk assessment* (IDT)

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. If the indication of the year of coming into effect is given to these referred standards, only the edition of indicated year constitutes the provision of this Standard but the revision and amendment made thereafter do not apply. The normative references without the indication of the year of publication apply only to the most recent editions (including the amendments).

JIS B 9960-1:1999 *Safety of machinery—Electrical equipment of machines—Part 1: General requirements*

Note : IEC 60204-1:1997 *Safety of machinery—Electrical equipment of machines—Part 1: General requirements* is equivalent to the said standard.

ISO/DIS 12100-1 *Safety of machinery—Basic concepts, general principles for design—Part 1: Basic terminology, methodology.*

ISO/DIS 12100-2 *Safety of machinery—Basic concepts, general principles for design—Part 2: Technical principles and specifications.*

3 Terms and definitions For the purposes of this Standard, the terms and definitions given in ISO/DIS 12100-1 and the following apply.

3.1 **harm** physical injury and/or damage to health or property

Note : In accordance with ISO/IEC Guide 51:1990, 3.4

3.2 **hazardous event** event that can cause harm

3.3 **safety measure** means that eliminates a hazard or reduces a risk

3.4 **residual risk** risk remaining after safety measures have been taken

4 General principles

4.1 **Basic concept** Risk assessment is a series of logical steps to enable, in a systematic way, the examination of the hazards associated with machinery. Risk assessment is followed, whenever necessary, by risk reduction as described in clause 5 of ISO/DIS 12100-1. When this process is repeated it gives the iterative process for eliminating hazards as far as possible and for implementing safety measures.

Risk assessment includes (see figure 1):

— risk analysis

1) determination of the limits of the machinery (see clause 5);

2) hazard identification (see clause 6);

3) risk estimation (see clause 7);

— risk evaluation (see clause 8).

Risk analysis provides the information required for the risk evaluation, which in turn allows judgements to be made on the safety of machinery.

Risk assessment relies on judgemental decisions. These decisions shall be supported by qualitative methods complemented, as far as possible, by quantitative methods. Quantitative methods are particularly appropriate when the foreseeable severity and extent of harm are high.

Quantitative methods are useful to assess alternative safety measures and to determine which gives better protection.

Note : The application of quantitative methods is restricted by the amount of useful data which is available, and in many applications only qualitative risk assessment will be possible.

The risk assessment shall be conducted so that it is possible to document the procedure which has been followed and the results which have been achieved (see clause 9).

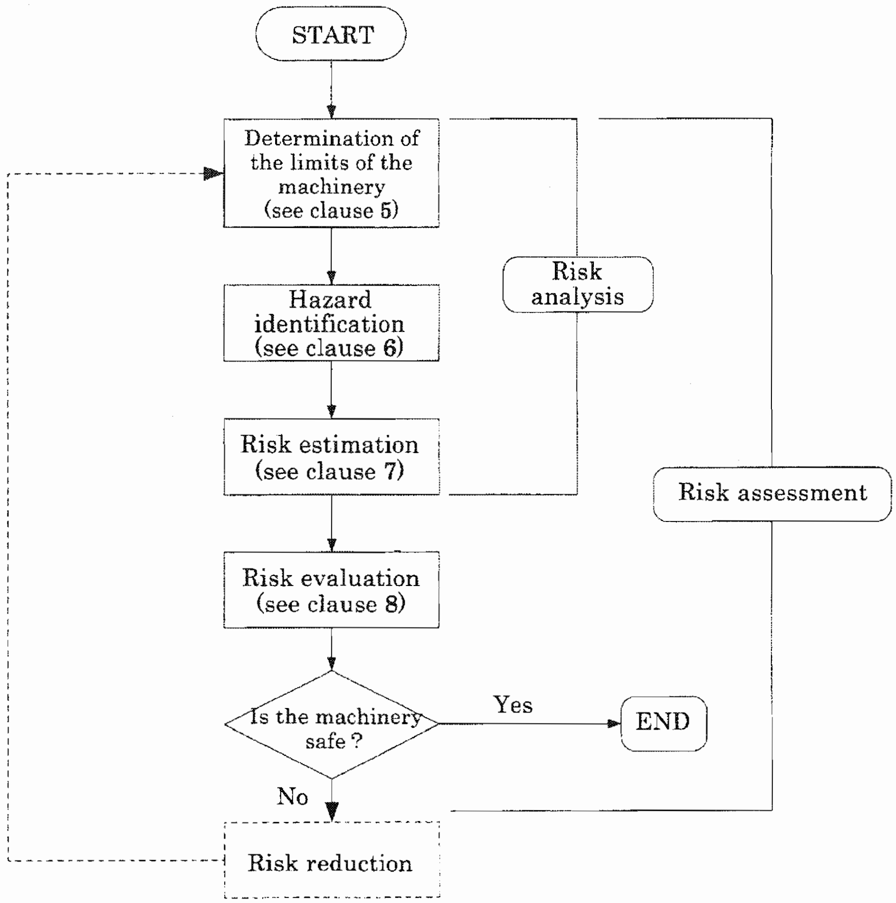

Figure 1 The iterative process to achieve safety

Note : Risk reduction and the selection of appropriate safety measures are not part of risk assessment. For further explanation, see clause 5 of ISO/DIS 12100-1 and ISO/DIS 12100-2.

4.2 Information for risk assessment The information for risk assessment and any qualitative and quantitative analysis shall include the following as appropriate:

— limits of the machinery (see clause 5);

— requirements for the life phases of the machinery [see 3.11 a) of ISO/DIS 12100-1];

— design drawings or other means of establishing the nature of the machinery;

— information concerning power supply;

— any accident and incident history;

— any information about damage to health.

The information shall be updated as the design develops and when modifications are required.

Comparisons between similar hazardous situations associated with different types of machinery are often possible, provided that sufficient information about hazards and accident circumstances in those situations is available.

The absence of an accident history, a small number of accidents or low severity of accidents shall not be taken as an automatic presumption of a low risk.

For quantitative analysis, data from databases, handbooks, laboratories and manufacturers' specifications may be used provided that there is confidence in the suitability of the data. Uncertainty associated with this data shall be indicated in the documentation (see clause 9).

Data based on the consensus of expert opinion derived from experience (e.g. DELPHI Technique—see annex B.8) can be used to supplement qualitative data.

5 Determination of the limits of the machinery Risk assessment shall take into account:

- the phases of machinery life [see 3.11 a) of ISO/DIS 12100-1]
- the limits of machinery (see 5.1 of ISO/DIS 12100-1) including the intended use (both the correct use and operation of the machinery as well as the consequences of reasonably foreseeable misuse or malfunction) in accordance with 3.12 of ISO/DIS 12100-1;
- the full range of foreseeable uses of the machinery (e.g. industrial, non-industrial and domestic) by persons identified by sex, age, dominant-hand usage, or limiting physical abilities (e.g. visual or hearing impairment, size, strength);
- the anticipated level of training, experience or ability of the foreseeable users such as:
  1) operators (including maintenance personnel or technicians);
  2) trainees and juniors;
  3) general public;
- exposure of other persons to the hazards associated with the machinery, where it can be reasonably foreseen.

6 Hazard identification All hazards, hazardous situations and hazardous events associated with the machinery shall be identified. Annex A gives examples to assist in this process (see clause 4 of ISO/DIS 12100-1, for further information on describing hazards generated by machinery).

Several methods are available for the systematic analysis of hazards. Examples are given in annex B.

7 Risk estimation

7.1 General After hazard identification (see clause 6), risk estimation shall be carried out for each hazard by determining the elements of risk given in 7.2. When determining these elements, it is necessary to take into account the aspects given in 7.3.

7.2 Elements of risk

7.2.1 Combination of elements of risk The risk associated with a particular situation or technical process is derived from a combination of the following elements:

— the severity of harm;

— the probability of occurrence of that harm, which is a function of:

1) the frequency and duration of the exposure of persons to the hazard;
2) the probability of occurrence of a hazardous event;
3) the technical and human possibilities to avoid or limit the harm (e.g. reduced speed, emergency stop equipment, enabling device, awareness of risks).

The elements are shown in figure 2 and additional details are given in 7.2.2 and 7.2.3.

Several methods are available for the systematic analysis of these elements. Examples are given in annex B.

Note : In many cases these elements cannot be exactly determined, but can only be estimated. This applies especially to the probability of occurrence of possible harm. The severity of possible harm cannot be easily established in some cases (e.g. in the case of damage to health due to toxic substances or stress).

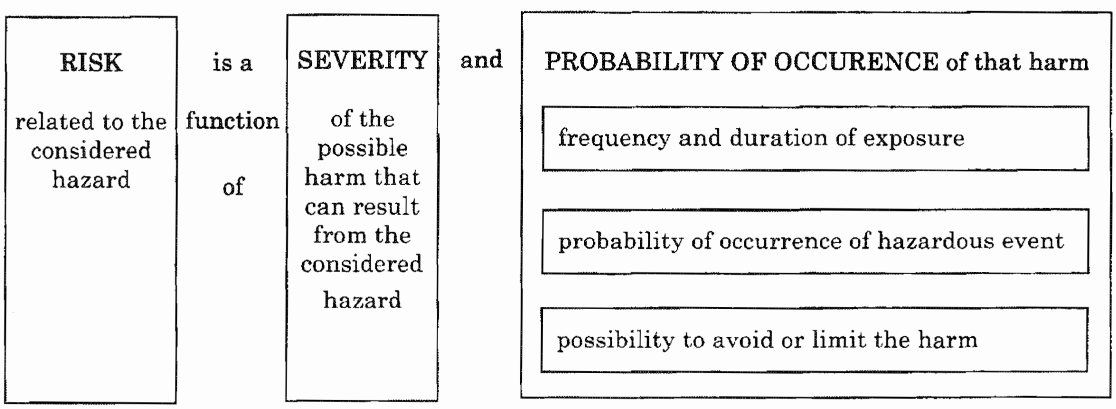

Figure 2 Elements of risk

7.2.2 Severity (degree of possible harm) The severity can be estimated by taking into account:

— the nature of what is to be protected:
   1) persons;
   2) property;
   3) environment;
— the severity of injuries or damage to health:
   1) slight (normally reversible);
   2) serious (normally irreversible);
   3) death;
— the extent of harm (for each machine):
   1) one person;
   2) several persons.

7.2.3 Probability of occurrence of harm The probability of occurrence of harm can be estimated by taking into account 7.2.3.1 to 7.2.3.3.

7.2.3.1 Frequency and duration of exposure

— Need for access to the danger zone (e.g. for normal operation, maintenance or repair);
— nature of access (e.g. manual feed of materials);
— time spent in the danger zone;
— number of persons requiring access;
— frequency of access.

7.2.3.2 Probability of occurrence of a hazardous event

— Reliability and other statistical data;
— accident history;
— history of damage to health;
— risk comparison (see 8.3).

Note : The occurrence of a hazardous event can be of technical or human origin.

7.2.3.3 Possibilities of avoiding or limiting harm

a) by whom the machinery is operated:
   1) by skilled persons;
   2) by unskilled persons;

3) unmanned;

b) the speed of appearance of the hazardous event:

1) suddenly;

2) fast;

3) slow;

c) any awareness of risk:

1) by general information;

2) by direct observation;

3) through warning signs and indicating devices;

d) the human possibility of avoidance or limiting harm (e.g. reflex, agility, possibility of escape):

1) possible;

2) possible under certain conditions;

3) impossible;

e) by practical experience and knowledge:

1) of the machinery;

2) of similar machinery;

3) no experience.

7.3 Aspects to be considered when establishing elements of risk

7.3.1 Persons exposed Risk estimation shall take into account all persons exposed to the hazards. This includes operators (see 3.21 of ISO/DIS 12100-1) and other persons for whom it is reasonably foreseeable that they could be affected by the machinery.

7.3.2 Type, frequency and duration of exposure The estimation of the exposure to the hazard under consideration (including long-term damage to health) requires analysis of, and shall account for, all modes of operation of the machinery and methods of working. In particular this affects the need for access during setting, teaching, process changeover or correction, cleaning, fault-finding and maintenance (see 3.11 of ISO/DIS 12100-1).

The risk estimation shall account for situations when it is necessary to suspend safety functions (e.g. during maintenance).

7.3.3 Relationship between exposure and effects The relationship between an exposure to a hazard and its effects shall be taken into account. The effects of accumulated exposure and synergistic effects shall also be considered. Risk estimation when considering these effects shall, as far as practicable, be based on appropriate recognized data.

Note : Accident data may be available to indicate the probability and severity of injury associated with the use of a particular type of machinery with a particular type of safety measure.

7.3.4 **Human factors** Human factors can affect risk and shall be taken into account in the risk estimation. This includes, for example:

— interaction of persons with the machinery;

— interaction between persons;

— psychological aspects;

— ergonomic effects;

— capacity of persons to be aware of risks in a given situation depending on their training, experience and ability.

The estimation of the ability of exposed persons shall take into account the following aspects:

— application of ergonomic principles in the design of the machinery;

— natural or developed ability to execute the required tasks;

— awareness of risks;

— level of confidence in carrying out the required tasks without intentional or unintentional deviation;

— temptations to deviate from prescribed and necessary safe working practices.

Training, experience and ability can affect the risk, but none of these factors shall be used as a substitute for hazard elimination, risk reduction by design or safeguarding where these safety measures can be implemented.

7.3.5 **Reliability of safety functions** Risk estimation shall take account of the reliability of components and systems. It shall:

— identify the circumstances which can result in harm (e.g. component failure, power failure, electrical disturbances);

— when appropriate use quantitative methods to compare alternative safety measures;

— provide information to allow the selection of appropriate safety functions, components and devices.

Those components and systems identified as providing safety-critical functions (see 3.13.1 of ISO/DIS 12100-1) need special attention.

When more than one safety-related device contributes toward a safety function, the selection of these devices shall be consistent when considering their reliability and their performance.

When safety measures include work organization, correct behaviour, attention, application of personal protective equipment, skill or training, the relatively low reliabil-

ity of such measures as compared to proven technical safety measures shall be taken into account in the risk estimation.

7.3.6 Possibility to defeat or circumvent safety measures Risk estimation shall take account of the possibility to defeat or circumvent safety measures. The estimation shall also take account of the incentive to defeat or circumvent safety measures, for example:

— the safety measure slows down production, or interferes with any other activities or preferences of the user;

— the safety measure is difficult to use;

— persons other than the operator are involved;

— the safety measure is not recognized by the user or is not accepted as suitable for its function.

The possibility to defeat a safety measure depends on both the type of safety measure (e.g. adjustable guard, programmable trip device) and its design details.

The use of programmable electronic systems introduces an additional possibility of defeat or circumvention if access to safety-related software is not properly designed and monitored. Risk estimation shall identify where safety-related functions are not separated from other machine functions, and shall determine the extent to which access is possible. This is particularly important when remote access for diagnostic or process correction purposes is required (see 11.3.4 of **JIS B 9960-1**:1999).

7.3.7 Ability to maintain safety measurers Risk estimation shall consider whether the safety measures can be maintained in the condition necessary to provide the required level of protection.

Note : If the safety measure cannot easily be maintained in correct working order, this may encourage the defeat or circumvention of the safety measure to allow continued use of the machinery.

7.3.8 Information for use Risk estimation shall take account of the proper implementation of clause 5 of **ISO/DIS 12100-2** for the information for use to be supplied with the machinery.

8 Risk evaluation

8.1 General After risk estimation, risk evaluation shall be carried out to determine if risk reduction is required or whether safety has been achieved. If risk reduction is required, then appropriate safety measures shall be selected and applied, and the procedure repeated (see figure 1). During this iterative process, it is important for the designer to check whether additional hazards are created when new safety measures are applied. If additional hazards do occur, they shall be added to the list of identified hazards.

The achievement of the risk reduction objectives (see 8.2) and a favourable outcome of risk comparison (see 8.3) give confidence that the machinery is safe.

8.2 Achievement of risk reduction objectives Achievement of the following conditions will indicate that the risk reduction process can be concluded.

a) The hazard has been eliminated or the risk reduced by:

   1) design or by the substitution for less hazardous materials and substances;

   2) safeguarding.

b) The safeguarding selected is of a type which, by experience, provides a safe situation for the intended use.

c) The type of safeguarding selected is appropriate for the application in terms of:

   1) probability of defeat or circumvention;

   2) severity of harm;

   3) hindrance to the execution of the required task.

d) The information on the intended use of the machinery is sufficiently clear.

e) The operating procedures for the use of the machinery are consistent with the ability of personnel who use the machinery or other persons who can be exposed to the hazards associated with the machinery.

f) The recommended safe working practices for the use of the machinery and the related training requirements have been adequately described.

g) The user is sufficiently informed about the residual risks in the different phases of the life of the machinery.

h) If personal protective equipment is recommended, the need for such equipment and the training requirements for its use have been adequately described.

i) Additional precautions are sufficient (see clause 6 of ISO/DIS 12100-2).

8.3 Comparison of risks As part of the process of risk evaluation, the risks associated with the machinery can be compared with those of similar machinery provided the following criteria apply:

— the similar machinery is safe;

— the intended use and the way both machines are made are comparable;

— the hazards and the elements of risk are comparable;

— the technical specifications are comparable;

— the conditions for use are comparable.

The use of this comparison method does not eliminate the need to follow the risk assessment process as described in this Standard for the specific conditions of use. For example, when a band saw used for cutting meat is compared with a band saw used for cutting wood, the risks associated with the different materials shall be assessed.

9 Documentation For the purpose of this Standard, documentation on risk assessment shall demonstrate the procedure which has been followed and the results which have been achieved. This documentation includes, when relevant:

a) the machinery for which the assessment has been made (e.g. specifications, limits, intended use);

b) any relevant assumptions which have been made (e.g. loads, strengths, safety factors);

c) the hazards identified;

— the hazardous situations identified;

— the hazardous events considered in the assessment;

d) the information on which risk assessment was based (see **4.2**);

— the data used and the sources (e.g. accident histories, experiences gained from risk reduction applied to similar machinery);

— the uncertainty associated with the data used and its impact on the risk assessment;

e) the objectives to be achieved by safety measures;

f) the safety measures implemented to eliminate identified hazards or to reduce risk (e.g. from standards or other specifications);

g) residual risks associated with the machinery;

h) the result of the final risk evaluation (see figure 1).

Annex A (informative) Examples of hazards, hazardous situations and hazardous events

Table A.1

No.	Hazards	Annex A of EN 292-2:1991/A1:1995	ISO/DIS 12100 Part 1	ISO/DIS 12100 Part 2
Hazards, hazardous situations and hazardous events				
1	Mechanical hazards due to: (1) machine parts or workpieces, e.g.: a) shape; b) relative location; c) mass and stability (potential energy of elements which may move under the effect of gravity); d) mass and velocity (kinetic energy of elements in controlled or uncontrolled motion); e) inadequacy of mechanical strength.	1.3	4.2	3.1, 3.2, 4.0
	(2) accumulation of energy inside the machinery, e.g.: f) elastic elements (springs); g) liquids and gases under pressure; h) the effect of vacuum.	1.5.3, 1.6.3	4.2	3.8, 6.2.2
1.1	Crushing hazard	1.3	4.2.1	
1.2	Shearing hazard			
1.3	Cutting or severing hazard			
1.4	Entanglement hazard			
1.5	Drawing-in or trapping hazard			
1.6	Impact hazard			
1.7	Stabbing or puncture hazard			
1.8	Friction or abrasion hazard			
1.9	High pressure fluid injection or ejection hazard	1.3.2	4.2.1	3.8
2	Electrical hazards due to:			
2.1	contact of persons with live parts (direct contact)	1.5.1, 1.6.3	4.3	3.9, 6.2.2
2.2	contact of persons with parts which have become live under faulty conditions (indirect contact)	1.5.1	4.3	3.9
2.3	approach to live parts under high voltage	1.5.1, 1.6.3	4.3	3.9, 6.2.2
2.4	electrostatic phenomena	1.5.2	4.3	3.9
2.5	thermal radiation or other phenomena such as the projection of molten particles and chemical effects from short circuits, overloads, etc.	1.5.1, 1.5.5	4.3	3.9
3	Thermal hazards, resulting in:			

Table A.1 (continued)

No.	Hazards	Annex A of EN 292-2:1991/A1:1995	ISO/DIS 12100 Part 1	ISO/DIS 12100 Part 2
3.1	burns, scalds and other injuries by a possible contact of persons with objects or materials with an extreme high or low temperature, by flames or explosions and also by the radiation of heat sources	1.5.5, 1.5.6, 1.5.7	4.4	
3.2	damage to health by hot or cold working environment	1.5.5	4.4	
4	Hazards generated by noise, resulting in:			
4.1	hearing loss (deafness), other physiological disorders (e.g. loss of balance, loss of awareness)	1.5.8	4.5	3.2, 4
4.2	interference with speech communication, acoustic signals, etc.			
5	Hazards generated by vibration			
5.1	Use of hand-held machines resulting in a variety of neurological and vascular disorders	1.5.9	4.6	3.2
5.2	Whole-body vibration, particularly when combined with poor posture			
6	Hazards generated by radiation			
6.1	Low-frequency, radio-frequency radiation; microwaves	1.5.10	4.7	
6.2	Infrared, visible and ultraviolet radiation			
6.3	X-and gamma rays			
6.4	Alpha, beta rays, electron or ion beams, neutrons	1.5.10, 1.5.11	4.7	3.7.3, 3.7.11
6.5	Lasers	1.5.12	4.7	
7	Hazards generated by materials and substances (and their constituent elements) processed or used by the machinery			
7.1	Hazards from contact with or inhalation of harmful fluids, gases, mists, fumes, and dusts	1.1.3, 1.5.13, 1.6.5	4.8	3.3 b), 3.4
7.2	Fire or explosion hazard	1.5.6, 1.5.7	4.8	3.4
7.3	Biological or microbiological (viral or bacterial) hazards	1.1.3, 1.6.5, 2.1	4.8	
8	Hazards generated by neglecting ergonomic principles in machinery design, as e.g. hazards from:			
8.1	unhealthy postures or excessive effort	1.1.2 d), 1.1.5, 1.6.2, 1.6.4	4.9	3.6.1, 6.2.1, 6.2.3, 6.2.4, 6.2.6
8.2	inadequate consideration of hand-arm or foot-leg anatomy	1.1.2 d), 2.2	4.9	3.6.2
8.3	neglected use of personal protection equipment	1.1.2 e)		3.6.6
8.4	inadequate local lighting	1.1.4		3.6.5
8.5	mental overload and underload, stress	1.1.2 d)	4.9	3.6.4

Table A.1 (continued)

No.	Hazards	Annex A of EN 292-2:1991/A1:1995	ISO/DIS 12100	
			Part 1	Part 2
8.6	human error, human behavior	1.1.2 d), 1.2.2, 1.2.5, 1.2.8, 1.5.4, 1.7	4.9	3.6, 3.7.8, 3.7.9, 5, 6.1.1
8.7	inadequate design, location or identification of manual controls	1.2.2		3.6.6, 3.7.8
8.8	inadequate design or location of visual display units	1.7.1		3.6.7, 5.2
9	Combination of hazards		4.10	
10	Unexpected start-up, unexpected overrun/overspeed (or any similar malfunction) from:			
10.1	failure/disorder of the control system	1.2.7, 1.6.3		3.7, 6.2.2
10.2	restoration of energy supply after an interruption	1.2.6		3.7.2
10.3	external influences on electrical equipment	1.2.1, 1.5.11, 4.1.2.8		3.7.11
10.4	other external influences (gravity, wind, etc.)	1.2.1		3.7.3
10.5	errors in the software	1.2.1		3.7.7
10.6	errors made by the operator (due to mismatch of machinery with human characteristics and abilities, see 8.6)	1.1.2 d), 1.2.2, 1.2.5, 1.2.8, 1.5.4, 1.7	4.9	3.6, 3.7.8, 3.7.9, 5, 6.1.1
11	Impossibility of stopping the machine in the best possible conditions	1.2.4, 1.2.6, 1.2.7		3.7, 3.7.1, 6.1.1
12	Variations in the rotational speed of tools	1.3.6		3.2, 3.3
13	Failure of the power supply	1.2.6		3.7, 3.7.2
14	Failure of the control circuit	1.2.1, 1.2.3, 1.2.4, 1.2.5, 1.2.7, 1.6.3		3.7, 6.2.2
15	Errors of fitting	1.5.4	4.9	5.5, 6.2.1
16	Break-up during operation	1.3.2	4.2.2	3.3
17	Falling or ejected objects or fluids	1.3.3	4.2.2	3.3, 3.8
18	Loss of stability/overturning of machinery	1.3.1	4.2.2	6.2.5
19	Slip, trip and fall of persons (related to machinery)	1.5.15	4.2.3	6.2.4
Additional hazards, hazardous situations and hazardous events due to mobility				
20	Relating to the travelling function			
20.1	Movement when starting the engine	3.3.2, 3.3.4		
20.2	Movement without a driver at the driving position	3.3.2		
20.3	Movement without all parts in a safe position	3.3.2		
20.4	Excessive speed of pedestrian-controlled machinery	3.3.4		
20.5	Excessive oscillations when moving	3.4.1		
20.6	Insufficient ability of machinery to be slowed down, stopped and immobilized	3.3.3, 3.3.5		
21	Linked to the work position (including driving station) on the machine			
21.1	Fall of persons during access to (or at/from) the work position	3.2.1, 3.2.3, 3.4.5, 3.4.7		

Table A.1 (continued)

No.	Hazards	Annex A of EN 292-2:1991/A1:1995	ISO/DIS 12100	
			Part 1	Part 2
21.2	Exhaust gases/lack of oxygen at the work position	3.2.1		
21.3	Fire (flammability of the cab, lack of extinguishing means)	3.2.1, 3.5.2		
21.4	Mechanical hazards at the work position: a) contact with the wheels; b) rollover; c) fall of objects, penetration by objects; d) break-up of parts rotating at high speed; e) contact of persons with machine parts or tools (pedestrian controlled machines).	 3.2.1 3.2.1, 3.4.3 3.2.1, 3.4.4 3.4.2 3.3.4		
21.5	Insufficient visibility from the work positions	3.2.1		
21.6	Inadequate lighting	3.1.2		
21.7	Inadequate seating	3.2.2		
21.8	Noise at the work position	3.2.1		
21.9	Vibration at the work position	3.2.1, 3.2.2, 3.6.3		
21.10	Insufficient means for evacuation/ emergency exit	3.2.1		
22	Due to the control system			
22.1	Inadequate location of manual controls	3.2.1, 3.3.1, 3.4.5		
22.2	Inadequate design of manual controls and their mode of operation	3.2.1, 3.3.1, 3.3.3		
23	From handling the machine (lack of stability)	3.1.3		
24	Due to the power source and to the transmission of power			
24.1	Hazards from the engine and the batteries	3.4.8, 3.5.1		
24.2	Hazards from transmission of power between machines	3.4.7		
24.3	Hazards from coupling and towing	3.4.6		
25	From/to third persons			
25.1	Unauthorized start-up/use	3.3.2		
25.2	Drift of a part away from its stopping position	3.4.1		
25.3	Lack or inadequacy of visual or acoustic warning means	1.7.4, 3.6.1		
26	Insufficient instructions for the driver/ operator	3.6		
Additional hazards, hazardous situations and hazardous events due to lifting				
27	Mechanical hazards and hazardous events			
27.1	from load falls, collisions, machine tipping caused by:			
27.1.1	lack of stability	4.1.2.1		
27.1.2	uncontrolled loading—overloading—overturning moments exceeded	4.2.1.4, 4.3.3, 4.4.2 a)		

Table A.1 (concluded)

No.	Hazards	Annex A of EN 292-2:1991/A1:1995	ISO/DIS 12100	
			Part 1	Part 2
27.1.3	uncontrolled amplitude of movements	4.1.2.6 a), 4.2.1.3		
27.1.4	unexpected/unintended movement of loads	4.1.2.6 c)		
27.1.5	inadequate holding devices/accessories	4.1.2.6 e), 4.4.1		
27.1.6	collision of more than one machine	4.1.2.6 b)		
27.2	from access of persons to load support	4.3.3		
27.3	from derailment	4.1.2.2		
27.4	from insufficient mechanical strength of parts	4.1.2.3		
27.5	from inadequate design of pulleys, drums	4.1.2.4		
27.6	from inadequate selection of chains, ropes, lifting and accessories and their inadequate integration into the machine	4.1.2.4, 4.1.2.5, 4.3.1, 4.3.2		
27.7	from lowering of the load under the control of friction brake	4.1.2.6 d)		
27.8	from abnormal conditions of assembly/testing/use/maintenance	4.4.1, 4.4.2 d)		
27.9	from the effect of load on persons (impact by load or counterweight)	4.1.2.6 b), 4.1.2.7, 4.2.3		
28	Electrical hazards			
28.1	from lightning	4.1.2.8		
29	Hazards generated by neglecting ergonomic principles			
29.1	insufficient visibility from the driving position	4.1.2.7, 4.4.2 c)		
Additional hazards, hazardous situations and hazardous events due to underground work				
30	Mechanical hazards and hazardous events due to:			
30.1	lack of stability of powered roof supports	5.1		
30.2	failure of accelerator or brake control of machinery running on rails	5.4		
30.3	failure or lack of deadman's control of machinery running on rails	5.4, 5.5		
31	Restricted movement of persons	5.2		
32	Fire and explosion	5.6		
33	Emission of dust, gases etc.	5.7		
Additional hazards, hazardous situations and hazardous events due to the lifting or moving of persons				
34	Mechanical hazards and hazardous events due to:			
34.1	inadequate mechanical strength; inadequate working coefficients	6.1.2		
34.2	failure of loading control	6.1.3		
34.3	failure of controls in personnel carrier (function, priority)	6.2.1		
34.4	overspeed of personnel carrier	6.2.3		
35	Falling of person from personnel carrier	1.5.15, 6.3.1, 6.3.2, 6.3.3		
36	Falling or overturning of personnel carrier	6.4.1, 6.4.2		
37	Human error, human behaviour	6.5		

Annex B (informative) Methods for analysing hazards and estimating risk

B.1 General There are many methods of hazard analysis and risk estimation and only a few are given in this annex. Also included are risk analysis techniques which combine hazard analysis with risk estimation.

Each method has been developed for particular applications. Therefore it may be necessary to modify some details for the special application for machinery.

There are two basic types of risk analysis: one is called the deductive method and the other the inductive method. In the deductive method, the final event is assumed and the events which could cause this final event are then sought. In the inductive method, the failure of a component is assumed. The subsequent analysis identifies the events which this failure could cause.

B.2 Preliminary Hazard Analysis (PHA) PHA is an inductive method whose objective is to identify, for all phases of life of a specified system/subsystem/component, the hazards, hazardous situations and hazardous events which could lead to an accident. The method identifies the accident possibilities and qualitatively evaluates the degree of possible injury or damage to health. Proposals for safety measures and the result of their application are then given.

PHA should be updated during the phases of design, building and testing, to detect new hazards and to make corrections, if necessary.

The description of the obtained results can be presented in different ways (e.g. table, tree).

B.3 "What-if" method The "what-if" method is an inductive method. For relatively simple applications, the design, operation and use of a machine is reviewed. At each step, "what-if" questions are formulated and answered to evaluate the effects of component failures or procedural errors on the creation of hazards at the machine.

For more complex applications, the "what-if" method can be best applied through the use of a checklist and by dividing the work, in order to assign certain aspects of the use of the machine to the persons having the greatest experience or skill in evaluating those aspects. Operator practices and job knowledge are audited. The suitability of equipment, the design of the machine, its control system and its safety equipment are assessed. The effects of the material being processed are reviewed, and the operating and maintenance records are audited. Generally, a checklist evaluation of the machine precedes use of the more sophisticated methods described below.

B.4 Failure Mode and Effects Analysis (FMEA) FMEA is an inductive method in which the main purpose is to evaluate the frequency and consequences of component failure. When operating procedures or operator error are significant, other methods can be more suitable.

FMEA can be more time-consuming than a fault tree, because for every component every mode of failure is considered. Some failures have a very low probability of occurrence. If these failures are not analysed in depth, this decision preferably should be recorded in the documentation.

The method is specified in IEC 60812.

B.5 Fault simulation for control systems In this inductive method, the test procedures are based on two criteria: technology and complexity of the control system. Principally, the following methods are applicable:

- practical tests on the actual circuit and fault simulation on actual components, particularly in areas of doubt, regarding performance identified during the theoretical check and analysis;
- a simulation of control behaviour (e.g. by means of hardware and/or software models).

Whenever complex safety-related parts of control systems are tested, it is usually necessary to divide the system into several functional subsystems and to exclusively submit the interface to fault simulation tests.

This technique can also be applied to other parts of machinery.

B.6 MOSAR method (Method Organized for a Systemic Analysis of Risks) MOSAR is a complete approach in ten steps. The system to be analysed (machinery, process, installation, etc.) is considered as number of subsystems which interact. A table is used to identify the hazards, the hazardous situations and the hazardous events.

The adequacy of the safety measures is studied with a second table, with a third table taking into account their interdependency.

A study, using known tools (such as FMEA) underlines the possible dangerous failures. This leads to the elaboration of accident scenarios. By consensus, the scenarios are sorted in a severity table.

A further table, again by consensus, links the severity with the objectives to be met by the safety measures and specifies the performance levels of technical and organizational measures.

The safety measures are then incorporated into logic trees and the residual risks are analysed via an acceptability table defined by consensus.

B.7 Fault Tree Analysis (FTA) FTA is a deductive method carried out from an event considered as unwanted, and enables the user of this method to find the whole set of critical paths that lead to the unwanted event.

Hazardous or top events are first identified. Then all combinations of individual failures that can lead to that hazardous event are shown in the logical format of the fault tree. By estimating the individual failure probabilities, and then using the appropriate arithmetical expressions, the top-event probability can be calculated. The impact of a system change on the top-event probability can readily be evaluated, and thus FTA makes it easy to investigate the impact of alternative safety measures. It has also been found useful in determining the cause of accidents.

The method is specified in IEC 61025.

B.8 DELPHI Technique A large circle of experts is questioned in several steps, whereby the result of the previous step together with additional information is communicated to all participants.

During the third or fourth step, the anonymous questioning concentrates on those aspects for which no agreement is reached so far.

Basically, Delphi is a forecasting method which is also used in generating ideas. This method is particularly efficient due to its limitation to experts.

Bibliography

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